Scheduling parameters in Production Planning and Control

Jan RESCHKE
Institute for Industrial Management (FIR) at RWTH Aachen University
Aachen, North Rhine Westphalia, Germany

and

Prof. Günther SCHUH
Institute for Industrial Management (FIR) at RWTH Aachen University
Aachen, North Rhine Westphalia, Germany

ABSTRACT

Nowadays one of the most challenging tasks of producing companies is the growing complexity due to the globalization and digitalization. Especially in high wage countries, the ability to deliver fast and to a fixed date gets more and more important. To achieve this logistic targets, it is necessary to optimize the Production Planning and Control (hereinafter PPC).
In times of Cyber-Physical Systems and the horizontal and vertical connection of whole producing companies, the PPC has to deal with huge and real-time data. In the practice as well as in theoretical models there is a research deficit regarding to scheduling parameters (hereinafter SP). These parameters determine, for example, the planning frequency, planning length or planning resolution. A suitable setting of these parameters is indispensable in order to be able to process the data mentioned above.
This is why, this study investigates the effects of a change of the scheduling parameters on a target system. The focused research questions are: How can the effect of a scheduling parameters-variation on the target system of the PPC can be displayed efficiently? Is it possible to review the effect of the scheduling parameters-variation quantitatively and to derive action options?

Keywords: Production management, scheduling parameters, real-time data, simulation model, System Dynamics, Production Planning and Control

1. INTRODUCTION

For many producing companies, especially SME´s, it is very difficult to handle the digitalization. However, they have to optimize their Production Planning and Control in order to fulfil flexible customer demands. The logistical targets, short delivery times and adherence to delivery dates, get more and more important and become a key differentiator in competitive markets. But how often do they have to plan? And how far in the future? In the authors researches it becomes obvious, that there are research deficits both in the practice and in the theory. Although some planning models, like the “Aachener PPS-Modell”, underline the importance of the scheduling parameters, there is no model or advice, how to adjust these parameters efficiently.
The following figures emphasize the hypothesis of a research deficit. One can see that in both figures neither existing theoretical models nor actual ERP-systems fulfill the last criteria, which aims on a setting recommendation for the scheduling parameters.

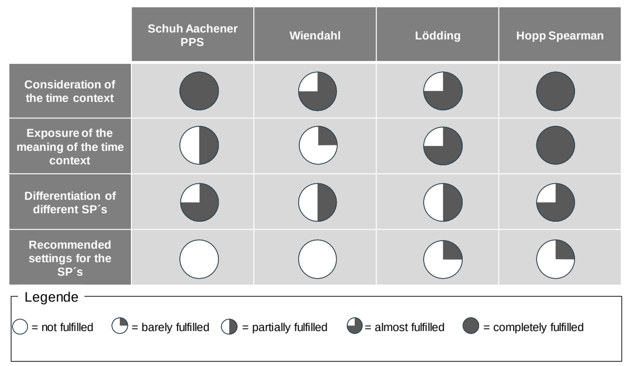

Figure 1: Analysis of theoretical models

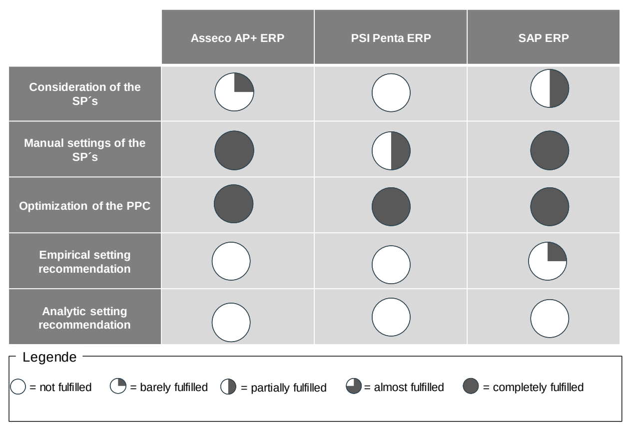

Figure 2: Analysis of ERP-systems

That is why the final objective of this study is to create a simulation model, which helps the user to choose optimal scheduling parameters for a given situation.

2. METHODIC PROCEDURE, SCHEDULING PARAMETERS

In the introduction was already mentioned, that this study focusses on the optimization possibilities in the PPC by a variation of scheduling parameters. This section deals with the description of scheduling parameters. A defined scheduling in the industrial context is carried out by the parameters of planning horizon, planning period, planning grid and the frozen zone as shown in Figure 3. [1–3]

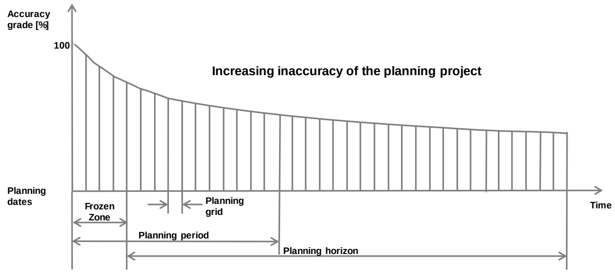

Figure 3: Differentiation of the scheduling parameters

Planning horizon
The planning horizon is the whole span of time, for which a planning is carried out [4]. With a higher time-difference from the planning origin, the quality of the planning decreases. The reason for this is, that unplanned machine stops or demand changes are unpredictable [5].

Planning period
A planning period is the time between two consecutive planning steps. The planning is adjusted in a planning step. An adjusting could be for example the reduction of the production because of an actualized demand prognosis. [2]

Planning grid
The planning grid determines how detailed a planning is carried out. The grid is the smallest span of time in the planning. It is comparable with the resolution or scanning in the control engineering. [1; 2]

Frozen zone
The frozen zone is the time between the planning step and the start of the production. In this time, it is not possible to change the planning anymore. A short frozen zone leads to a high flexibility regarding customer demands. However, it becomes more and more difficult to achieve a high degree of capacity utilization. [3]

The research approach was, to determine a target system for the PPC and define the influences of the scheduling parameters on the individual targets. These influences were illustrated with the method System Dynamics. This is a method, that allows to model complex systems qualitatively as well as quantitatively [6]. The basis of this simulation method are the qualitative “casual loop diagrams”, which are transformed to quantitative “stock and flow diagrams” afterwards. This is the actual simulation, which can lead to quantitative results.

3. Target system

In this section the target system of the simulation model is presented. This factors can lead to an improvement of the PPC through an optimized setting of the scheduling parameters. The weighting of the individual targets can be determined by the user. The targets “improvement of the adherence to delivery date”, “shorten the lead time”, “increase of the capacity utilization” and “reducing of stocks” are operationalized and described in a characteristic number. In a separate step, the rescheduling effort is evaluated and compared to the improvement potential.

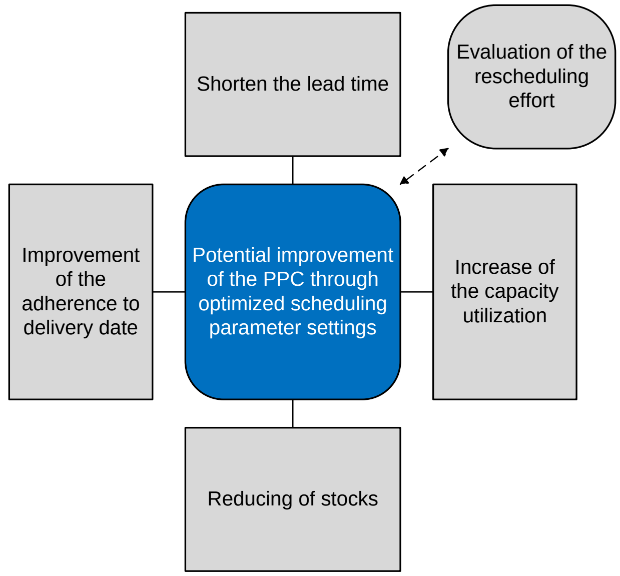

Figure 4: Target system of the model

In a further step this main targets were split into designing sizes. However, it must be taken into account that only those designing sizes that can be influenced by optimizing the planning are included in the model.

This can be shown well in a simple example, that actually is part of the model. The lead time can be divided into the process time, the setup time and the transition time. While the process time and setup time can be influenced by the planning, the cycle time can only be influenced by technological changes. Therefore, in this case, for example, it was decided not to include the process time into the model.

In the end, the design variables were subdivided into individual planning tasks to make the influence of the scheduling parameters more comprehensible. This shall be shown again with the example lead time. The complete subdivision can be seen in the following figure 5.

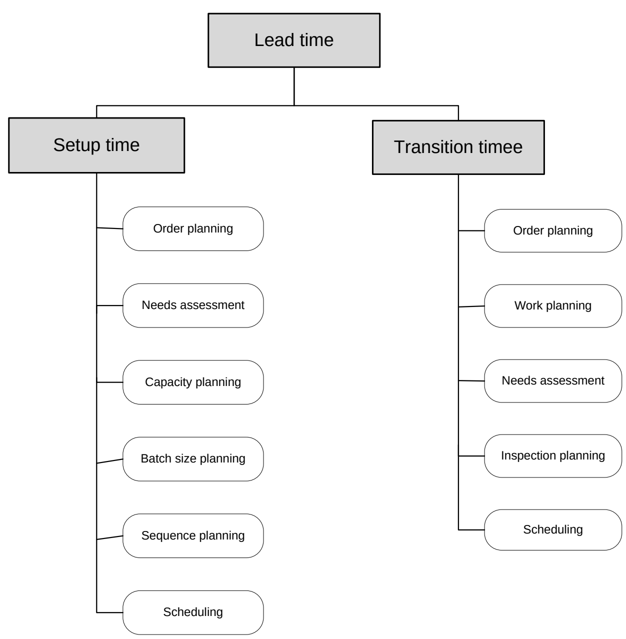

Figure 5: Designing sizes and planning tasks lead time

Just like in this example, the other target sizes were also subdivided into designing sizes and individual planning tasks. For reasons of space, only the designing variables are listed in this article.
Capacity utilization:
- Increasing the capacity utilization
- Increasing the capacity stress
- Alignment of the capacity stress
Stock:
- Prebooking / Reservations
- Safety stocks
- Free available stocks
Adherence to delivery date:
- Supply of the pre-production
- Adherence to the delivery date of external suppliers
- Compliance with the planned setup times
- Compliance with the planned transition times
- Compliance with the start dates

4. Casual loop diagrams

Up to now, the scheduling parameters have been introduced and explained, and a target system relevant to the Production Planning and Control has been developed. With regard to the research deficit, the influence of the scheduling parameters on the target system will be inquired qualitatively in the following section. Like mentioned before, System Dynamics is a strong method to improve the comprehension of complex problems. Therefore, the first step is to display the qualitative influence in a casual loop diagram.
An example for these diagrams is shown in the following figure (example: lead time):

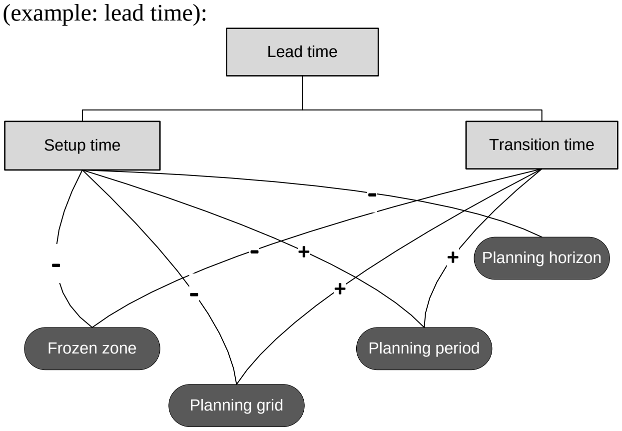

Figure 6: Interdependency lead time

The procedure shall be shown again with the example of the lead time. The scheduling parameters influence the planning tasks, which can be found in figure 6. These influences were summarized and their impact on the design size evaluated. A positive impact is pictured by a "+". Positive means always an increase of the designing size. So in this case, for example, the "+" from planning period to setup time is not really positive, because it provides an extension of the setup time. The other case is pictured with a "-".
The notation always refers to an increase in the scheduling parameter.

An extension of the frozen zone offers a higher rate of security during the planning and also better opportunities to sum up batch sizes in the production. This results in a shortening of the lead time. Moreover, a longer frozen zone enables the planner to organize an optimized order planning. This leads to shorter waiting times in front of following machines.

A coarser planning grid (lower resolution) enables the company, inter alia, to sum up orders to higher batch sizes. This leads to a reduction of setup times, because the demands are summarized more efficiently and the machines do not have to be equipped as often.
However, this leads to an extension of the waiting times in front of the machines and so to a higher transition time.

The frequency and proximity of reality with which a planning is carried out is significantly determined by the planning period. The quality of the planning decreases through an extension of the planning period. This makes it more difficult to optimize the batch size and to sum up orders. Because of spontaneous machine stops, that could not be considered in the planning, the waiting times in front of machines increase. Overall a higher planning period leads consequently to a higher setup and transition time and thus to a negative influence on the lead time.

The planning horizon focusses long term decisions. That is why there is no impact on the transition time. Regarding the setup time, a longer planning horizon enables the planner to optimize the summing up of different orders.

5. Simulation model

The research deficit is, as already mentioned in the introduction, the lack of recommendations for the scheduling parameters. The developed simulation model tries to evaluate a change of the scheduling parameters in a given situation. The concrete recommendation can be a reasonable task for future studies.
Firstly, the basely structure of the model is presented:

1) Analysis of the current state
   - Determination of the actual schedule parameters settings
   - Carry out the simulation with the current setting
   - Identification of the values of the targets
2) Potential Analysis
   - Variation of the schedule parameters setting (manually)
   - Identification of potentials of the individual targets with different settings
   - Determination of the overall potential
3) Evaluation of the rescheduling effort
   - Calculation of the rescheduling effort
   - Comparison of the rescheduling effort with the potentials
4) Improvement potential of the PPC
   - Overall improvement potential (targets potential minus rescheduling effort)
   - Showing the biggest lever for improvement
   - Showing potential options for actions

The form-specific relationship of the overall potential (OP) is composed of the respective targets, their weightings (X_n) and the correction by the rescheduling effort. This is shown in the following formula:

$$OP = (X_1 * Potential\_Lead\_Time + X_2 * Potential\_Capacity\_Utilization + X_3 * Potential\_Stock + X_4 * Potential\_adherence\_to\_delivery\_date) - Rescheduling\_Effort \quad \text{Eq. (1)}$$

$$X_1 + X_2 + X_3 + X_4 = 1 \qquad \text{Eq. (2)}$$

The weightings X_n can be chosen by the user in a range between 0 and 1. To compare the current state and the state with variated settings, the overall improvement potential (OIP) can be calculated:

$$OIP = OP_2 - OP_1 \qquad \text{Eq. (3)}$$

If this value is positive, there can be generated a positive effect by changing the scheduling parameters.

There are a lot of formulas to calculate the concrete potential. In this paper the method will be explained with the example *Potential_Lead_Time*: First of all, this potential can be divided into the designing sizes *Potential_Setup_Time* and *Potential_Transition_Time*. In the casual loop diagrams the influence of each individual scheduling parameter on these sizes have been defined. These variables again result from the sizes I_{FZ}, I_{PG}, I_{PP}, I_{PH}. I_{FZ} stands for the influence of the frozen zone on the designing size I_{PG} for the influence of the planning grid IPP for the influence of the planning period and I_{PH} for the influence of the planning horizon. The formula-specific relation between these sizes can be derived from the dependencies taken from the casual loop diagrams:

$$Potential\_Setup\_Time = I_{FZ}\_Setup\_Time + I_{PG}\_Setup\_Time + I_{PP}\_Setup\_Time + I_{PH}\_Setup\_Time \qquad \text{Eq. (4)}$$

$$I_{FZ}\_Setup\_Time = (-2w - s) * FZ \qquad \text{Eq. (5)}$$

$$I_{PG}\_Setup\_Time = (-w - 4m) * PG \qquad \text{Eq. (6)}$$

$$I_{PP}\_Setup\_Time = (w + 3m) * PP \qquad \text{Eq. (7)}$$

$$I_{PH}\_Setup\_Time = (-w - m) * PH \qquad \text{Eq. (8)}$$

$$Potential\_Transition\_Time = I_{FZ}\_Transition\_Time + I_{PG}\_Transition\_Time + I_{PP}\_Transition\_Time \qquad \text{Eq. (9)}$$

$$I_{FZ}\_Transition\_Time = (-3w - m) * FZ \qquad \text{Eq. (10)}$$

$$I_{PG}\_Transition\_Time = (m + 4s) * PG \qquad \text{Eq. (11)}$$

$$I_{PP}\_Transition\_Time = w * PP \qquad \text{Eq. (12)}$$

By default, the parameters weak (w), middle (m) and strong (s) are defined as w=0,01, m=0,05, s=0,1.
The scheduling parameters FZ, PG, PP and PH are normed. That means, that the value is divided through the maximal value of the respective scheduling parameter. The maximal value can be defined individual. By default, the values are Max_FZ=30 days, Max_PG=1 week, Max_PP=6 months and Max_PH=2 years.
In the following figure the System Dynamics model of the lead time is presented:

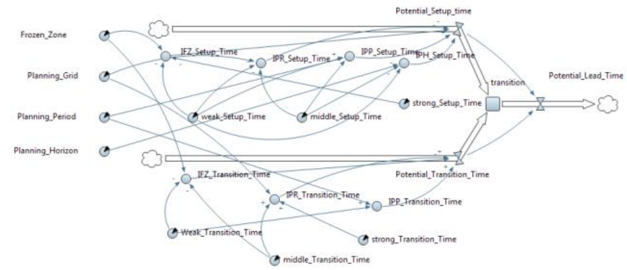

Figure 7: System-Dynamics model of the lead time

In this way formulas were generated for each individual target.
The third step of the structure is to calculate the rescheduling effort. The rescheduling effort results from the extra effort of each individual scheduling parameter. The effort of the scheduling parameter frozen zone for example results from an addition of the planning tasks influenced by a change of this parameter.
This results in the following relation:

$$Rescheduling\ Effort = 23 * E_{FZ} + 40 * E_{PG} + 40 * E_{PP} + 19 * E_{PH} \qquad \text{Eq. (13)}$$

$$A_{PV} + A_{PR} + A_{PP} + A_{PH} = 1 \qquad \text{Eq. (14)}$$

E_{FZ} means for example the individual effort of the user to change the length of the frozen zone.

6. Conclusion and Outlook

The aim of this study was, to quantify the impact of scheduling parameters on the Production Planning and Control. Therefore, the author created a target system and researched the influence of the individual scheduling parameters on this system.
Through the developed simulation model, it is possible to evaluate different scheduling parameter settings. Moreover, the user can assess the targets and efforts individually.

However, the overall target, to generate a recommendation for the individual setting was not reached yet. The author is optimistic, that this can be done based on the simulation model. In addition, the model, at best, must be evaluated in a practice test. Until now, it was only reviewed with a fictional case.

A mature version of the model could later be integrated into ERP systems and thus also contribute in practice to optimizations in the PPC.

An important topic in all research studies nowadays is Industry 4.0, or Cyber-Physical Systems. The “German Academic Society for Production Engineering” defines Industry 4.0 as the ability to network resources, services and people in production based on cyber-physical systems in real-time. This works on basis of the Internet of Things (IoT). [7]

This revolution will lead into more and more information that will be generated in real-time. This occurs a huge complexity, especially for the PPC. However, it also opens up possibilities for companies to gain competitive advantages. Essentially for this revolution are the horizontal connection, that connects the actors within a supply chain by using the IoT and the vertical connection, that connects the departments in one company with each other and that connects the production to a cyber-physical system. Through this an automatically, real time production control could be possible, which would change the whole planning process completely.

7. Acknowledgement

The presented research is result of the Cluster of Excellence (CoE) on "Integrative Production Technology for High-Wage Countries" funded by Deutsche Forschungsgemeinschaft (DFG). Within the CoE "Integrative Production Technology for High-Wage Countries" several institutes at RWTH Aachen University are conducting research on fundamentals of a sustainable production strategy. The authors would like to thank the German Research Foundation DFG for the kind support within the Cluster of Excellence „Integrative Production Technology for High-Wage Countries.

7. REFERENCES

[1] D. Much; H. Nicolai, **PPS-Lexikon**, Berlin: Cornelsen Girardet, 1995.

[2] C. Paegert, **Entwicklung eines Entscheidungsunterstützungssystems zur Zeitparametereinstellung**, Aachen: Shaker, 1997.

[3] I. Göpfert; D. Braun; M. Schulz, **Automobillogistik**, Wiesbaden: Springer Gabler, 2013.

[4] K. Bichler; R. Krohn; P. Philippi, **Gabler Kompakt-Lexikon Logistik**, Wiesbaden: Gabler Verlag, 2005.

[5] R. Hackstein, **Produktionsplanung und -steuerung (PPS)**, Düsseldorf: VDI-Verl., 1989.

[6] W. Boysen, **Kybernetisches Denken und Handeln in der Unternehmenspraxis**, Wiesbaden: Gabler, 2011.

[7] T. Bauernhansl; G. Reinhart; J. Krüger; G. Schuh, **WGP-Standpunkt Industrie 4.0**, Darmstadt: Wissenschaftliche Gesellschaft für Produktionstechnik, 2016.